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Measuring Irrigation Performance in Africa

Mark Svendsen
Mandy Ewing
Siwa Msangi

Environment and Production Technology Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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AUTHORS

Mark Svendsen
External Consultant, Environment and Production Technology Division
Email: msvendsen@peak.org

Mandy Ewing, International Food Policy Research Institute
Research Analyst, Environment and Production Technology Division
Email: m.ewing@cgiar.org

Siwa Msangi, International Food Policy Research Institute
Senior Research Fellow, Environment and Production Technology Division
Email: s.msangi@cgiar.org

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ABSTRACT

The paper develops indicators to look at the performance of the irrigation sector in Sub-Saharan Africa, where demand for food is high and irrigation has a proven potential to boost levels of agricultural productivity. By looking at six indicator categories—institutional framework, water resource use, irrigation area, irrigation technology, agricultural productivity, and poverty and food security—we assess the potential for improving performance in the agricultural food security sector through increasing irrigation sector investments. The indicators on water resource use indicate ample room for further development of the resource. The share of cultivated area equipped for irrigation in Africa is about a third of the world average and just one-sixth of the value for Asia. The low coverage of irrigation technology and the slow rate of growth in coverage clearly represent a lost opportunity for Africa and a tremendous potential for future investment and policy effort. Finally, African countries produce 38 percent of their crops (by value) from approximately 7 percent of their cultivated land on which water is managed, which again suggests that additional investment in irrigation would pay large benefits. The disproportionate contribution to agricultural production of Africa's small irrigated area suggests that returns on additional investment in irrigation would be high, both in terms of greater food security for the continent and greater production of export-quality agricultural goods.

Keywords: Africa; irrigation performance; agricultural production; water resources

1. INTRODUCTION

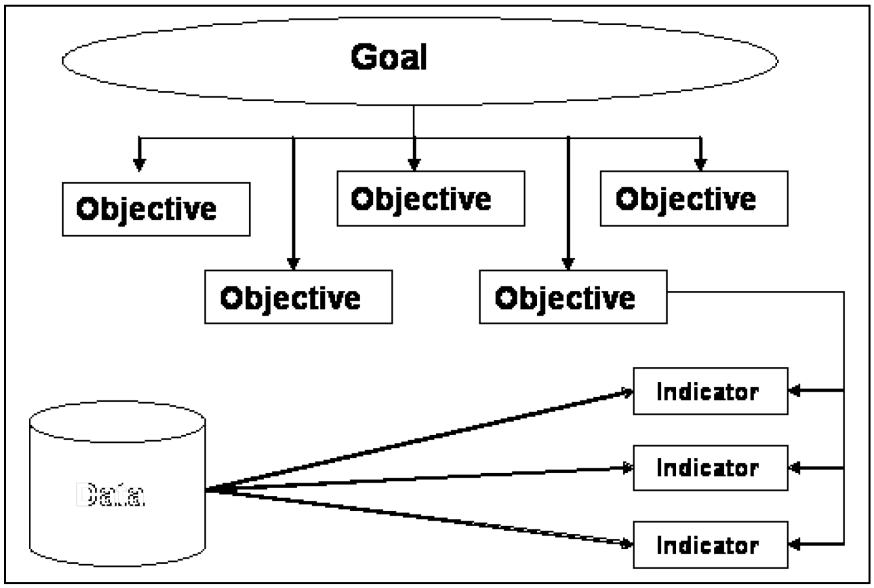
Continued concern over food security in Africa and a persistent agricultural productivity lag behind other regions have refocused attention on the importance of key investments in the African agricultural sector. Irrigation is an investment that has been promoted persistently by donors, research analysts, and scientists within the international agricultural development community to address that lag. At the same time, irrigation is only one of the productivity-improving capital investments and technological inputs that are deficient in Africa. Others include fertilizer, advanced seed delivery systems, postharvest processing facilities, and access to markets. Irrigation stands out strongly among these, however, because of its role in stabilizing yields in the face of climatic variability, which has increased notably in recent times and is projected to increase further under almost all future climate change scenarios. In addition, much of Africa is expected to experience reduced annual precipitation, which would, along with higher temperatures, enhance the potential productivity-enhancing effects of irrigation.

This paper attempts to collect sector performance indicators to permit cross-country benchmarking and analysis of irrigation sector performance over time for Africa. Indicators are identified and a baseline is provided against which future improvements in infrastructure services can be measured, making it possible to monitor achievements resulting from increased financial flows. The water resource and irrigation sector is defined to include water storage and water distribution infrastructure and includes both large-scale public and small-scale private and communal investments.

Conceptual Framework

Although terminology sometimes varies among different organizations, the concepts involved in the hierarchy extending from goals to indicators, and the purpose of each, are fairly standard (Figure 1) At the upper level, a *goal* presents a broad statement of what an activity hopes to achieve. At the next level, *objectives* are specific, measurable, appropriate, realistic, and time-bound statements describing in greater detail what the activity defined by the goal hopes to achieve. Objectives do not say *how* something will be done, only what is to be accomplished. *Indicators* are variables used to measure achievement of an objective. They are directly related to the objective, measurable, and neutral, in that they do not contain judgments about particular values of the indicator at any given time. They simply provide a way to measure change. That change can then be evaluated against targets established separately for the various indicators. It should be noted that any targets set will be subject to creep as a result of changes induced by global warming, and such exogenous influences will have to be accounted for in any subsequent evaluation based on these indicators.

Figure 1. Basic monitoring framework.



It is important that indicators are variables that can change in response to the external interventions. They cannot be static parameters; nor can they be variables not reasonably expected to respond to the intervention.

To use indicators to measure change, it is necessary to know their beginning values, since they usually are non-zero prior to the intervention. In addition to identifying an appropriate set of indicators, this paper also establishes baseline values for those indicators that will allow changes in their values to be assessed.

The overarching goal of irrigation infrastructure and water resource investments in Africa is to reduce hunger and poverty by raising the productivity of agriculture. To achieve this goal, various sectors must play a role, formulating specific objectives. These relate to institutions, the water resource, technology, productivity, and poverty and food security. These topical areas form the framework for the indicators selected for use in the paper.

Although indicators for the higher level of goals and the lower level of activities are also sometimes specified and measured, the current exercise is an indicative one that relates to a general program concept and not to a particular project or specific activities. Consideration of indicators is thus restricted to the intermediate level of an assumed set of objectives for the program.

Methodology

In this paper, we assess six thematic areas of importance for tracking irrigation expansion in Africa:

- *Institutional framework*—by which we try and capture certain key qualitative characteristics of the organization and governance of water and irrigation within the country
- *Water resource utilization*—where we describe the overall patterns of water usage and water's availability and distribution within the country
- *Irrigated area*—an indicator that captures the extent of investment in irrigation
- *Irrigation technology*—which helps to differentiate between the various types of irrigation and how various countries have been equipped

- *Agricultural productivity*—which is a first-order measure of irrigation performance in agriculture and of the variation of rainfed and irrigated yields across countries
- *Poverty and food security*—which tries to address the linkage between performance of the agricultural sector and the wider agricultural economy on human welfare indicators

Most of the indicators were drawn from Food and Agriculture Organization (FAO) global databases; data were also drawn from World Bank and IFPRI data sources, although the IFPRI data were used only where constructing useful thematically related indicators from the global databases was impossible. Although a good deal of the data is quantitative, some important information is qualitative, such as the data on the institutional characteristics of the irrigation sector. The performance indicators were selected to provide comprehensive coverage of important aspects of the water resource system and irrigation performance, constrained by data availability and a concern for parsimony. Information on data sources appears in the source notes to the tables.

Despite best efforts, there are gaps in the range of *useful* performance indicators in the paper. In particular, data on institutional characteristics, such as the pricing of water, are not available. Because it was deemed important to cover the countries in the paper consistently, the subset of indicators selected was restricted to those that could be obtained for comparison across all or nearly all African countries.

Africa in Context

The most recent comprehensive water resource and irrigation data of the 53 African countries are from the 2005 AQUASTAT survey conducted by FAO. The final report, titled "Irrigation in Africa in Figures," provides a general summary of the survey findings and should be referred to for in-depth context. Table 1 presents basic descriptive features of Africa compared with the world for variables concerning water and agriculture. Both Sub-Saharan Africa and Africa as a whole have around one hectare (ha) of cultivated land per person; however, Africa—especially Sub-Saharan Africa—has a much higher population density than the world average (81 inhabitants per square kilometer [km^2] in Sub-Saharan Africa versus the world average of 47 inhabitants per km^2). Moreover, internal renewable water availability per hectare of land is less than two-thirds of global availability, reflecting both regional scarcity and the transboundary nature of water flows in the region.

A striking difference between Africa and the world as a whole is that African countries withdraw less than half as much water per capita as does the world in general (241 cubic meters per year [m^3/year] compared with 599 m^3/year). This reflects the fact that African countries irrigate only about 6 percent of their collective cropland, compared with a world average of about 18 percent.

In summary, African countries have less renewable water per unit area and a higher population density than the world as a whole. They have a higher percentage of the population engaged in agriculture (more than half the economically active population) with a slightly smaller average farm size (a little more than one hectare per agricultural worker). They withdraw only a quarter as much water for human uses as does the world as a whole, and the irrigated share of their cropland is less than one-fourth of the world average.

Table 1. Basic descriptive features of Africa and the world.

Variable	Unit	World	Africa	Sub-Saharan Africa
Total area	1,000 ha	13,442,788	3,030,967	2,455,678
Cultivated area (2003)	1,000 ha	1,541,488	225,284	197,189
- % of total area	%	11	7	8
- per inhabitant	ha	0.24	0.25	0.27
- per econ. active person engaged in agriculture	ha	1.16	1.07	1.02
Total population (2005)	1,000 inhab	6,464,452	887,965	732,836
Population density	inhab/km2	47	78	81
Rural population as % of total population	%	51	60	62
Econ. active population engaged in agriculture	%	21	56	—
	km3/year	101,736	20,380	19,830
Precipitation	mm/year	1,169	1,045	1,136
Internally renewable water resources	km3/year	43,744	5,570	5,463
- per inhabitant	m3/year	6,859	6,273	7,455
Total water withdrawals	km3/year	3,818	214	120
- agricultural	km3/year	2,661	184	105
- % of total water withdrawal	%	70	86	87
- domestic	km3/year	380	21	13
- % of total water withdrawal	%	10	10	11
- industrial	km3/year	777	9	4
- % of total water withdrawal	%	20	4	3
- in % of renewable water resources	%	9	4	2
- per inhabitant	m3/year	599	241	163
Irrigation (total area equipped)	1,000 ha	277,285	13,416	7,117
% of cultivated area	%	18	6	4

Sources: FAO AQUASTAT database, accessed November 19, 2007 (FAO 2007a), and FAO (2005).
Notes: Sub-Saharan Africa includes South Africa. Some or all data missing for British Indian Ocean Territories, Equatorial Guinea, Mayotte, Saint Helena, Seychelles, and Western Sahara. If more than half of the observations were empty, then values were not calculated.

African hydrology is notable for its steep gradients in moisture availability both in the region and in individual countries, particularly in the Sudano-Sahelian and East African regions. As a result, moisture regimes change quickly over fairly short distances, and countrywide averages of moisture conditions mask considerable diversity. Another implication of the steep rainfall gradients is that the regions where rainfall contours are very close together are particularly vulnerable to changes in rainfall resulting from global warming, since changes here are likely to be more extreme.

Irrigated area in Sub-Saharan Africa totals a bit more than 7 million hectares, and about twice that when including northern Africa; individual country areas range from almost none in Lesotho to nearly 3 million hectares, nearly a fifth of the total for Africa, in Egypt. Irrigated areas and the share of the potential developed for individual countries are shown in Table 2.

Irrigation potentials, as reported by the FAO (2005) and AQUASTAT databases, reflect area measures reported by individual countries and do not follow a uniform definition. At a minimum, the potential encompasses land resources suitable for irrigation. But it may also reflect water availability or geographical constraints such as distance, slope, land suitability, and other environmental considerations. In all cases, however, the potential includes all land currently under water management (FAO 2005).

Tables 1 and 2 refer only to areas equipped for irrigation and do not incorporate other forms of agricultural water management like non-equipped cultivated wetlands and inland valley bottoms or non-equipped flood recession cropping areas and small-scale peri-urban irrigated agriculture. Getting more information and insights on the performance of those systems will be very important for the development of irrigated agriculture in Africa. Equally important, approximately 20 percent of the area equipped with irrigation is not operational at any one point in time, on average in Africa. Those areas need to be located and constraints to operation in them need to be identified.

Table 2. Irrigated area.

Country	Irrigated area (ha)	Share of irrigation potential (%)
Algeria	569,418	112
Angola	80,000	2
Benin	12,258	4
Botswana	1,439	11
Burkina Faso	25,000	15
Burundi	21,430	10
Cameroon	25,654	9
Cape Verde	2,780	89
Central African Republic	135	0
Chad	30,273	9
Comoros	130	43
Congo, Dem. Rep.	72,750	15
Congo, Rep. of	2,000	1
Côte d'Ivoire	10,500	0
Djibouti	1,012	42
Egypt	3,422,178	77
Equatorial Guinea	—	—
Eritrea	21,590	12
Ethiopia	289,530	11
Gabon	4,450	1
Gambia, The	2,149	3
Ghana	30,900	2
Guinea	94,914	18
Guinea-Bissau	22,558	8
Kenya	103,203	29
Lesotho	2,637	21

Table 2. (Continued)

Country	Irrigated area (ha)	Share of irrigation potential (%)
Liberia	2,100	0
Libya	470,000	1175
Madagascar	1,086,291	72
Malawi	56,390	35
Mali	235,791	42
Mauritania	45,012	18
Mauritius	21,222	64
Morocco	1,484,160	89
Mozambique	118,120	4
Namibia	7,573	16
Niger	73,663	27
Nigeria	293,117	13
Rwanda	8,500	5
Sao Tome and Principe	9,700	91
Senegal	119,680	29
Seychelles	260	26
Sierra Leone	29,360	4
Somalia	200,000	83
South Africa	1,498,000	100
Sudan	1,863,000	67
Swaziland	49,843	53
Tanzania	184,330	9
Togo	7,300	4
Tunisia	394,000	70
Uganda	9,150	10
Zambia	155,912	30
Zimbabwe	173,513	47

Source: FAO AQUASTAT database, accessed November 19, 2007 (FAO 2007a).

Irrigated area can be classified by the size of the scheme—small, medium, and large (Table 3). Due to differing criteria for this classification, however, comparisons across countries are difficult. In general, the majority of irrigated area comes from large-scale schemes, with the exceptions of Madagascar and Senegal.

Table 3. Size of full/partial irrigation schemes, reporting countries.

Country	Year	Size of scheme	Criteria (ha)	Area (ha)	Total area under full/partial control (ha)
		M	<500	363,508	
Algeria	2001	L	>500	149,860	513,368
		S	<50	1,723	
		M	50–100	1,328	
Benin	2002	L	>100	7,922	10,973
		S	<1,000	8,215	
Burkina Faso	2001	L	>1,000	10,385	18,600
		S	<50	800	
		M	50–100	500	
Burundi	2000	L	>100	5,660	6,960
		S	<20	650	
		M	20–200	7,300	
Cameroon	2000	L	>200	14,500	22,450
		S	<100	6,538	
Chad	2002	L	>100	23,915	30,273
		S	<100	1,480	
		M	100–1,000	220	
Congo, Dem. Rep.	1995	L	>1,000	8,300	10,000
		S	<1,000	11,750	
Cote d'Ivoire	1994	L	>1,000	36,000	47,750
		S	<200	191,827	
Ethiopia	2001	L	>200	97,703	289,530
		S	<50	7798	
Guinea	2001	L	>50	125,880	20,386
		S	<1	661	
Guinea-Bissau	1996	M	>5	7,901	8,562
		S	5–1,000	48,048	
		M	0.5–5,950	427,000	
Kenya	2003	L	213–6,200	12,458	103,203
		S	<100	175	
Lesotho	2003	L	>100	2,462	2,637
		S	<200	800,000	
		M	200–2,500	179,641	
Madagascar	2000	L	>2500	106,650	1,086,291
		S	<100	23,068	
		M	100–1000	2,000	
Mali	2000	L	>1000	72,431	97,499
		S	<40	13,655	
		M	40–100	16,536	
Mauritania	2004	L	>100	14,821	45,012

Table 3. (Continued)

Country	Year	Size of scheme	Criteria (ha)	Area (ha)	Total area under full/partial control (ha)
		S	<2	4,548	
		M	2–40	328	
Mauritius	2002	L	>40	16,346	21,222
		S	n/a	441,430	
		M	n/a	334,130	
Morocco	2004	L	n/a	682,600	1,458,160
		S	<50	6,389	
		M	50–500	19,647	
Mozambique	2001	L	>500	92,084	118,120
Niger	2005	L	>25	13,663	13,663
		S	<50	63,000	
Senegal	2002	L	>50	39,180	102,180
Seychelles	2003	M	2–70	260	260
		S	<100,000	443,070	
		M	100,000–500,000	417,150	
Sudan	2000	L	>500,000	870,750	1,730,970
		S	<50	6,419	
		M	50–500	10,000	
Swaziland	2002	L	>500	33,424	49,843
		S	<50	5,533	
		M	50–500	71,212	
Tanzania	2002	L	>500	107,243	184,330
		S	<50	165,000	
		M	50–200	79,000	
Tunisia	2000	L	>200	123,000	367,000
		S	<50	100	
		M	50–500	680	
Uganda	1998	L	>500	4,800	5,580
		S	n/a	11,000	
		M	n/a	7,372	
Zambia	2002	L	n/a	37,015	55,387
		S	n/a	81,575	
Zimbabwe	1999	L	n/a	91,938	173,513

Source: FAO (2005).
Notes: In Kenya only, the criteria used to delineate size groupings correspond to the range of sizes under various control regimes: small refers to the range of schemes that smallholders control; medium refers to the range of schemes that are under private commercial control; and large refers to the range of schemes implemented by the National Irrigation Board. "n/a" = no size criteria are available.

Agro-ecological Zone Framework

The particular characteristics and disposition of irrigation within subregions of the continent take on different characteristics and functions that are suited to the peculiarities of their environment, and that have been adapted to both the socioeconomic conditions and the realities of the agro-ecological zones in which they are found. As a result, it is useful to present the FAO subregional classifications to describe the various agro-ecological environments found within the continent. These are summarized in Table 4.

Using these classifications, we can discuss the particular characteristics of irrigation potential and purpose in the relevant regions of Africa more easily and can relate them to the irrigation potential and outcomes that are found within those regions.

Northern Region

The region inhabited north of the Saharan desert includes five countries, each with access to the Mediterranean coast: Morocco, Algeria, Tunisia, Libya, and Egypt. The countries constitute the second largest region in Africa in terms of land area, accounting for 19 percent of total area in Africa. In terms of cultivable area, however, the northern region has the least amount of area when compared with other mainland regions (the Indian Ocean island region technically has the least). The relatively low availability of cultivable land reflects the level of precipitation in the region, which ranges from 750 millimeters in the extreme northwest of Morocco to nearly zero millimeters in the south of Egypt (FAO 2005).

Sudano-Sahelian Region

The characteristics of this region are largely dominated by Sudan, which covers 29 percent of the area and has employed traditional irrigation systems for a very long time—prior to the installation of modern storage and diversion schemes adopted in the early 20th century (FAO 1986). The Sudan has traditionally used irrigation for sustaining its cotton crop and has fairly large irrigation systems that draw most of its water (up to 95 percent) from the Nile, with a small fraction coming from groundwater or other sources. The climate of this region is generally dry, and the country itself has the lowest density of people on the continent—on the order of 13 inhabitants/km^2 (FAO 2005).

Other countries in this region with significant water diversions for irrigation are those in the Senegal River basin or in other large river basins (Lake Chad basin). These countries are characterized by some nomadic pastoralism, but they also grow and irrigate cereals, including rice, as well as millet and sorghum. Although extensive irrigation and large projects have not reached beyond the Sudan, successful schemes on a significant scale have given sustenance to food and cash crops. A number of the countries in the region are landlocked, including Burkina Faso, Chad, Mali, and Niger.

Table 4. Agro-ecological zones of Africa

Region	Countries in zone
Northern	Algeria, Egypt, Libya, Morocco, Tunisia
Sudano-Sahelian	Burkina Faso, Cape Verde, Chad, Djibouti, Eritrea, The Gambia, Mali, Mauritania, Niger, Senegal, Somalia, Sudan
Eastern	Burundi, Ethiopia, Kenya, Tanzania, Uganda, Rwanda
Gulf of Guinea	Benin, Côte d'Ivoire, Ghana, Guinea, Guinea-Bissau, Liberia, Nigeria, Sierra Leone, Togo
Central	Angola, Cameroon, Central African Republic, Congo (Rep. of), Dem. Rep. of Congo, Equatorial Guinea, Gabon, Sao Tome and Principe
Southern	Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe
Indian Ocean Islands	Comoros, Madagascar, Mauritius, Seychelles

Source: FAO (2005).

Eastern Africa Region

Of the six countries in this region (Ethiopia, Kenya, Rwanda, Uganda, Tanzania, and Burundi), four are landlocked; only Kenya and Tanzania have access to the sea. On average, 37 percent of the total arable area is actually under production, with large areas in the arid zones (which makes up 70 percent of Kenya's total area, for example) being unusable for agriculture and only marginally usable for livestock. While parts of this region, especially near the inland lakes (such as Victoria), are relatively fertile and well watered, many other parts are of a more fragile agro-ecology.

Given the diverse climate and terrain, irrigation has played an important part in boosting the agricultural performance of cash crops in Ethiopia and Kenya, although the vast majority of the food crops grown in these countries are rainfed.

Gulf of Guinea Region

Nigeria accounts for 44 percent of the total area (2.1 million km^2) of this region. Bordered by the Atlantic Ocean to the south and the Sudano-Sahelian region to the north, there is a considerable degree of climatic variation along the north-south axis of all the countries within this region—from the wet and tropical in the south to the dry Sudan in the north. Given this, precipitation varies significantly between the north and the south, which makes country-level averages somewhat misleading when trying to gauge the extent to which agricultural areas are served by climate-driven water resources. The variation of rainfall within a country such as Benin, for example, is just over 1,000 millimeters per year, and the evapotranspiration of crops also increases considerably (almost quadrupling from 1,500 millimeters per year in the south of Togo to northern Nigeria). This creates a varied scope for irrigation within this region, with some areas experiencing much more severe water stress than others.

Central Africa Region

Relative to the previous three regions, this area of Africa is relatively well supplied with water resources, although there is variation from tropical dry or wet environments to the equatorial. Of the population that lives within all the eight countries covered by this region, 56 percent live within the Democratic Republic of Congo. The region also has fairly low population densities when compared with other regions of Africa (going as low as five inhabitants per km^2 in Gabon). This region typifies the general imbalance of groundwater resources that exists within Africa, as most groundwater resides in the Congo Basin, with relatively high levels of precipitation and relatively low levels of irrigation demand, compared with other agricultural regions within Africa (Giordano 2005).

Southern Africa Region

This region contains some prominent desert areas but is also bordered by oceans to the west, south, and east—which provide a moderating influence to coastal areas—and has close to Mediterranean conditions in areas like the Cape of Good Hope. The inland areas vary from scrub-desert terrains to more moderate environments at higher altitudes, as well as tropical and subtropical areas elsewhere. Given the wide north-to-south transept of this region, there is a wide variety of precipitation and water availability, from the more humid areas like Malawi to the drier climes of Namibia. The agro-ecological conditions, and crop evapotranspiration, as a result, also see a wide variation from moist regions like Mozambique, which has favorable areas for sugarcane and other tropical agriculture, to other areas like South Africa, which are better suited for dryland agriculture—especially in the absence of irrigation.

Indian Ocean Islands

The single island of Madagascar represents 99 percent of the area that would fall into this classification (including that of Comoros, Mauritius, and Seychelles). Even across the island of Madagascar itself conditions vary from that of semi-arid to tropical humid, which gives it a variety of growing conditions for agriculture. Madagascar also has a relatively low population density (34 inhabitants/km^2) compared with some of the other smaller islands (some of which exceed 400 inhabitants/km^2). Compared with the rest of these islands, Madagascar also dominates in terms of cultivated area in the region (3.8 million hectares).

2. INDICATORS

Institutional Framework

A country's institutional framework specifies the location of investment planning and implementation responsibilities; designates the managing entity, or set of entities, for irrigation system operations; defines regulatory authorities; specifies revenue assessment and collection procedures; establishes dispute resolution processes; and assigns responsibility for allocating and protecting water rights.

However, no database consolidates this information for the countries of Africa. Moreover, from a performance assessment point of view, it is often difficult to specify in the abstract what desirable changes in the institutional framework would look like. That is to say, it is difficult to specify an "ideal" or "preferred" institutional framework without considering a particular country context and taking into account the characteristics of that context.

Nevertheless, some broadly accepted principles provide a standard for judging the desirability of particular institutional configurations. These principles change from time to time as experience accumulates, as conditions change globally, and as the focus of the development community shifts. Currently, some widely accepted principles of good water resource development and management are the following:

- Integrated water resource planning
- A closed financing loop, from service user to service provider
- Beneficiaries sharing in the costs of irrigation development
- Separating water resource management functions from sector management
- Farmers' involvement, and especially women farmers' involvement, in irrigation management
- Organizing irrigation along hydrologic boundaries
- Secure water rights

In contrast to these values or principles, specific institutional configurations are often indeterminate, meaning that it is impossible to make abstract normative judgments about important considerations, such as

- how large irrigation management units should be;
- which particular system of water rights is best;
- how much regulation should be imposed on irrigation service providers;
- how much decision-making authority should be lodged at a given level; and
- whether a river basin management organization with command and control authority is always necessary.

Table 5. Institutional framework indicators.

Country	Water policy?**	Specialized agency for basin-level management?	Dedicated irrigation infrastructure development entity?	Empowerment of Water User Associations?	Irrigation strategy?**	Irrigation action plan?**
Algeria	Yes	No	Yes	No	Yes	No
Angola	Ongoing	No	No	No	Ongoing	No
Benin	Yes	No	No	Yes	No	No
Botswana	Yes	No	No	No	No	No
Burkina Faso	Yes	No	No	Yes	Yes	Yes
Burundi	Ongoing	No	No	No	No	Yes
Cameroon**	Yes	No	No	Yes	Yes	Yes
Cape Verde	Ongoing	No	No	No	No	No
Central African Republic	Yes	No	No	No	No	Yes
Chad	Yes	No	No	Yes	No	No
Comoros	Yes	No	No	No	No	Yes
Congo, Dem. Rep.	Yes	No	No	No	No	No
Congo, Rep. of	Yes	No	Yes	Yes	No	Yes
Cote d'Ivoire	Yes	No	No	No	Yes	Yes
Djibouti	Yes	No	Yes	No	No	Yes
Egypt**	Yes	Yes	Yes	Early stage	Yes	Yes
Equatorial Guinea	No	No	No	No	No	Yes
Eritrea	No	No	No	No	No	No
Ethiopia**	Yes	Yes	Yes	Yes	Yes	Yes
Gabon	Ongoing	No	No	No	No	No
Gambia, The	No	No	No	Yes	No	No
Ghana	Yes	No	No	No	Yes	No
Guinea	Yes	No	No	Yes	Ongoing	Ongoing
Guinea-Bissau	Yes	No	Yes	Yes	No	No
Kenya	Yes	Yes	No	Yes	No	No
Lesotho	Yes	No	No	Yes	No	No
Liberia	No	No	No	No	No	No
Libya**	Yes	No	No	No	Yes	Yes
Madagascar	Yes	Yes	No	Yes	Yes	Yes
Malawi**	Yes	No	No	Yes	Yes	No
Mali	Yes	Yes	No	No	Yes	Yes
Mauritania	Yes	Yes	Yes	Yes	Yes	Yes
Mauritius	Yes	No	Yes	Yes	No	No
Morocco	Yes	Yes	Yes	Yes	Yes	Yes

Table 5. (Continued)

Country	Water policy?**	Specialized agency for basin-level management?	Dedicated irrigation infrastructure development entity?	Empowerment of Water User Associations?	Irrigation strategy?**	Irrigation action plan?**
Mozambique**	Yes	Yes	No	No	No	No
Namibia**	Yes	No	No	Yes	No	No
Niger	Yes	Yes	No	Yes	No	No
Nigeria**	Yes	Yes	No	Yes	Yes	Yes
Rwanda	Yes	No	No	No	No	No
Sao Tome and Principe	No	No	No	No	No	No
Senegal	Yes	Yes	No	Yes	No	No
Seychelles	Yes	No	Yes	No	No	No
Sierra Leone	No	No	Yes	No	No	No
Somalia	No	No	No	No	No	No
South Africa	Yes	Yes	Yes	Yes	Yes	Yes
Sudan**	Yes	No	No	Yes	Yes	Yes
Swaziland**	Yes	No	No	No	No	No
Tanzania**	Yes	Yes	Yes	Yes	Yes	No
Togo	Ongoing	No	No	No	No	Yes
Tunisia	Yes	No	Yes	Yes	Yes	Yes
Uganda**	Yes	No	Yes	Yes	No	No
Zambia**	Yes	No	No	No	Yes	Yes
Zimbabwe	Yes	No	Yes	No	No	No

Sources: The country responses for each of the questions and countries marked with double asterisks (**) are from the unpublished report of a workshop organized by World Bank Water and Food Group in Ouagadougou, Burkina Faso, March 2007. All other answers are interpreted from country profiles in FAO (2005).

This is not to say that we have no knowledge that would help us to make such choices, but rather that the right configuration in a particular country, and the correct pathway to reach that configuration, is country and time specific. This makes it very difficult to define a set of regionwide indicators that can be used to measure "progress" in institutional change resulting from an irrigation investment program.

Nevertheless, an interim set of indicators was formed based on a workshop in Ouagadougou organized by the World Bank Water and Food Group in March 2007, which produced some useful information relating to institutional characteristics in a sample of countries. Participants from 28 African countries attended and were queried about the development of water and irrigation policies, as well as irrigation action plans (Table 5). This information was expanded to all countries in Africa using the survey of institutional frameworks for irrigation development found in country profiles from the AQUASTAT survey of Africa (FAO 2005). In addition to those asked at the workshop, three additional questions were formulated that attempt to demonstrate the level of specialization and decentralization that is found in the management of irrigation resources in each country (see Table 5, questions 2–4). Again, these questions are not based on a sound theoretical model that links certain institutional arrangements with sound outcomes. For example, a "yes" value across the table is not a sufficient condition for good irrigation performance outcome—as likely Ethiopia, Mauritania, South Africa, and Tanzania make up a varied group in terms of sector performance despite receiving the same responses. Another limitation of

these questions is that they convey neither the length of time over which these institutional characteristics have held nor their specific quality (except for a few responses shown, such as "early stage" and "ongoing"). Finally, some responses might be reflections of reforms pushed by donors that may not reflect a change in the paradigm of water management within the country—or that might be so in the future but haven't yet taken hold. Therefore, at the moment, all we can note is whether certain elements are "in place" that might at least provide a starting point for good sector performance in the future—even if we cannot tie it to concrete outcomes in the past (as observed in data).

So additional effort is needed to think through the question of whether it is possible to specify a set of reliable indicators that would measure progress in the evolution of national water-related institutional frameworks in Africa, and if so, what those indicators would be.

Water Resource Utilization

This section identifies indicators that help us assess the impact of increased investments in irrigation. It also documents the current utilization and reliability of water resources for agriculture in African countries as a basis for future assessments of change.

Irrigation investment can be expected to do several things: It may expand the area under irrigation and increase the amount of water used in irrigated agriculture. It may also make supply more reliable by providing increased storage of surface water in reservoirs. This in turn may benefit other water-using sectors as well as agriculture. Like surface water reservoirs, groundwater aquifers may also serve to buffer fluctuations in the supply of irrigation water. The four indicators selected to measure changes in this area are described below. Indicator values for Africa as well as comparable values for other national groupings are shown in Table 6.

Table 6. Water resource utilization indicators.

Country	Total water withdrawals as % of TARWR	Total agricultural water withdrawals as % of TARWR	Total dam capacity / total surface water (%)	Total dam capacity (m3/capita)	Groundwater development (abstraction as % of recharge)
Algeria	52.0	33.8	59.2	183	170.6
Angola	0.2	0.1	5.0	280	0.0
Benin	0.5	0.2	0.2	6	—
Botswana	1.6	0.7	3.6	215	4.5
Burkina Faso	6.2	5.5	63.8	370	—
Burundi	2.3	1.8	—	0	—
Cameroon	0.3	0.3	5.5	925	—
Cape Verde	7.3	6.7	—	—	—
Central African Republic	0.0	0.0	—	0	—
Chad	0.5	0.4	—	—	0.9
Comoros	0.8	0.4	—	0	—
Congo, Dem. Rep.	0.0	0.0	—	n/a	—
Congo, Rep. of	0.0	0.0	0.0	2	0.0
Côte d'Ivoire	1.1	0.7	48.7	679	—

Table 6. (Continued)

Country	Total water withdrawals as % of TARWR	Total agricultural water withdrawals as % of TARWR	Total dam capacity / total surface water (%)	Total dam capacity (m3/capita)	Groundwater development (abstraction as % of recharge)
Djibouti	6.3	1.0	—	0	
Egypt	117.2	101.2	301.8	2,283	407.7
Equatorial Guinea	0.4	0.0	—	0	—
Eritrea	9.2	8.7	1.6	21	—
Ethiopia	5.1	4.7	3.2	47	—
Gabon	0.1	0.0	0.2	159	0.0
Gambia, The	0.4	0.3	—	0	—
Ghana	1.8	1.2	286.1	6,802	—
Guinea	0.7	0.6	1.0	200	—
Guinea-Bissau	0.6	0.5	—	0	—
Kenya	9.0	7.2	13.7	124	15.0
Lesotho	1.7	0.3	93.3	1,569	3.0
Liberia	0.0	0.0	—	0	—
Libya	721.0	597.3	385.0	66	528.6
Madagascar	4.4	4.2	0.1	27	8.7
Malawi	5.8	4.7	0.2	3	2.5
Mali	6.5	5.9	17.0	1,007	0.5
Mauritania	14.9	13.2	8.0	290	293.3
Mauritius	26.4	17.8	5.0	75	14.9
Morocco	43.4	38.0	84.7	511	29.8
Mozambique	0.3	0.3	30.3	3,307	0.2
Namibia	1.7	1.2	4.5	349	6.7
Niger	6.5	6.2	0.3	8	5.2
Nigeria	2.8	1.9	15.8	339	—
Rwanda	2.9	2.0	—	—	—
Sao Tome and Principe	0.3	—	1.8	248	—
Senegal	5.6	5.2	4.3	151	3.3
Seychelles	—	—	—	12	—
Sierra Leone	0.2	0.2	0.2	40	0.0
Somalia	22.4	22.3	—	0	9.1
South Africa	25.0	15.7	59.3	629	59.3
Sudan	57.8	55.9	14.1	251	4.0
Swaziland	23.1	22.3	15.2	567	—
Tanzania	5.7	5.1	4.8	109	0.4

Table 6. (Continued)

Country	Total water withdrawals as % of TARWR	Total agricultural water withdrawals as % of TARWR	Total dam capacity / total surface water (%)	Total dam capacity (m3/capita)	Groundwater development (abstraction as % of recharge)
Togo	1.1	0.5	19.0	278	—
Tunisia	57.5	47.1	85.2	253	39.2
Uganda	0.5	0.2	—	—	—
Zambia	1.7	1.3	100.8	9,599	0.4
Zimbabwe	21.0	16.6	735.7	7,917	7.8
Northern	267.5	218.6	203.8	540	306.7
Sudano-Sahelian	22.8	21.8	9.7	270	38.1
Eastern	5.6	4.9	5.5	78	3.1
Gulf of Guinea	1.7	1.2	47.1	1,049	0.0
Central	0.1	0.1	1.7	156	0.0
Southern	9.2	6.2	99.0	2,999	17.8
Indian Ocean Islands	4.5	4.2	0.1	27	8.7
SSA average	1.5	1.3	11.2	838	17.5
Africa average	3.8	3.3	14.6	780	72.9
Asia average	19.4	15.8	12.0	870	—
World average	7.4	5.2	7.6	1,031	—

Sources: Columns 1–4, FAO AQUASTAT database November 12, 2007 (FAO 2007a)[Perhaps it would be best to identify the date you accessed the database (as you did in Table 1.1) and to give the parenthetical citation--i.e., FAO 2007a)]; column 5, Global Groundwater Information System (GGIS), v. 23 (2004), accessed at www.igrac.nl.
Notes: Total water withdrawals = water withdrawn for agriculture, domestic, and industrial purposes. TARWR = total actual renewable water resources, the sum of internal and external renewable water resources, taking into consideration the quantity of flow reserved for upstream and downstream countries through formal agreements or treaties and reduction of flow due to upstream consumption. Dam capacity = total cumulative capacity of large dams expressed as theoretical initial capacity, without adjustment for silting or other changes over time. Total surface water = TARWR less groundwater. Weighted averages are calculated by dividing the sum of the numerator by the sum of the denominator. Agro-ecological zone averages are weighted by country area. Africa average does not include Western Sahara and island countries not in the study.
— = data not readily available.

Total Water Withdrawals

Total water withdrawals for all uses as a percentage of the total renewable water resources of the country considers both ground and surface water, and total renewable water resources include inflows from upstream riparian countries and deduct obligated outflows to downstream riparian environments. The indicator thus shows the fraction of the renewable water resources of the country that is presently being withdrawn for human use.

Total water withdrawals across the region are very low, averaging just 3.8 percent of available supply. The northern countries of Libya, Egypt, Morocco, and Tunisia dwarf all other countries in this regard. In Sub-Saharan Africa, South Africa with its large commercial irrigation sector, urban conglomerations, and well-developed industrial base and Sudan with its vast Gezira scheme stand out.[1]

[1] Throughout the analysis we have weighted the averages in the indicator tables in order to account for the large share of the sector represented by countries in the northern region, Sudan, South Africa, and Madagascar, among other outliers.

By contrast, total withdrawals in Asia comprise almost one-fifth of available water (19.4 percent). The world average (7.4 percent) is nearly double the level for Africa.

Water resource investments should increase the value of this indicator, particularly if investments are directed at irrigation, since irrigation usually consumes the lion's share of withdrawals. At the same time, investments in water-storage and large-scale conveyance facilities can also provide the basis for increased withdrawals for municipal and industrial water supplies.

Obviously if values of this indicator become very large, severe environmental damage would be expected. Moreover because countrywide averages subsume wide diversity, local-level assessments are obviously required as well. The generally low values of this indicator suggest, however, scope for additional withdrawals to support rural livelihoods, food security, and economic growth.

Agricultural Water Withdrawals

This indicator measures the amount of water withdrawn for agricultural uses as a percentage of total renewable water resources. This value will always be less than the value for the total water withdrawal indicator, since that indicator also includes municipal and industrial use. This indicator value should rise strongly and directly in response to investments in irrigation development.

The picture for agricultural withdrawals is similar to that for total withdrawals, with Egypt, Libya, and Sudan again standing out dramatically from a low overall average. Low agricultural withdrawals in the humid central Africa region are understandable given the wider scope in the region for rainfed agriculture.

The Asian value of this indicator is five times that of Africa; the world value is one-third greater.

Storage Capacity

Storage smoothes variability in river discharges and gives managers greater control over allocating water among different sectors and users and with different temporal rainfall patterns. This indicator is the ratio of total reservoir capacity in the country to the total renewable annual surface water resource. It measures the amount of surface water available to the country that can be stored for later use. The average for Africa is about 15 percent of average annual discharge. For comparison, dams in the Colorado River Basin in the United States help store about 400 percent of the Colorado's average annual discharge. The storage ratio will obviously respond directly to investments that create new storage. Another good indicator of reliability of water supply would be a ratio of high flow to low flow in the river throughout the year. Unfortunately, data are not readily available to compute this indicator.

The reservoir capacity ratio of the region is actually higher than the average for either Asia or the world as a whole. Capacity, though, is concentrated in few countries—Egypt, Ghana, Libya, Zambia, Lesotho, South Africa, and Zimbabwe—when reckoned as a share of available surface water. In some cases, Zambia and Lesotho for example, this capacity is used largely for hydropower generation as shown by the relatively small fraction of the water resource withdrawn for agriculture in these countries. The lack of storage in the Central African region, which has considerable hydropower potential, results from the relative abundance of supply, relatively low population density, and densely forested and difficult terrain. Note that of the 25 largest rivers in the world, only three are situated in Africa. Similar trends between the countries are shown by calculating total dam capacity per person, with Ghana, Zimbabwe, and Zambia dominating the shares. The quality of data reported in the FAO AQUASTAT database suggests further reviews of storage data.

Groundwater Abstraction

This indicator measures the amount of groundwater pumped as a percentage of total renewable groundwater in the country. Data in this column are somewhat sparse because only a little over half of the countries report values. With the exception of northern Africa, Mauritania, and South Africa, all the values are very small and therefore suggest potential for much greater development. Shallow groundwater

aquifers are good water sources for individual and small community irrigation systems; where such types of irrigation development are targeted, this indicator is expected to increase.

Irrigated Area

This section presents indicators for irrigation development and documents their current values in the Africa and other regional groupings. These indicators are crucial ones since they will respond directly to irrigation investment programs in the various countries, indicating change over time within individual countries, and changes in relative positions among countries.

In addition to area of classically equipped irrigation, many African countries also contain cultivated areas with more basic facilities or no permanent facilities at all, in which water is managed informally. These include areas of flood recession agriculture, spate irrigation, and cultivated wetlands. In spate irrigation, floodwaters originating from mountain catchments are diverted from riverbeds and spread over extensive areas. Because of their less reliable water supply and limited control, these areas are generally less productive than areas equipped for classical irrigation. Locally, however, they may be very important, and offer opportunities for upgrading to improve productivity.

Five indicators can be used to assess impacts of irrigation improvement programs on the extent of irrigation and irrigation technology. Values of these indicators for Africa—and comparable values for other national groupings—are shown in Table 7.

Table 7. Irrigation area indicators.

Country	Percent			Average rate of growth of irrigated area, 1973–2003	Average rate of growth of irrigated area, 2000–03
	Total irrigation equipped area / cultivated area	Irrigation-equipped area actually irrigated / total equipped area	Total water-managed area / cultivated area		
Algeria	6.9	79.6	6.9	2.9	0.1
Angola	2.2	43.8	11.1	0.2	0.0
Benin	0.4	23.0	0.7	4.7	0.0
Botswana	0.4	96.0	2.1	0.0	0.0
Burkina Faso	0.6	97.3	1.1	4.9	0.0
Burundi	1.6	—	7.8	1.4	0.0
Cameroon	0.4	—	0.4	4.0	0.0
Cape Verde	6.2	65.5	6.2	1.4	0.0
Central African Rep.	0.0	51.1	0.0	—	26.0
Chad	0.8	86.5	4.3	4.1	2.3
Comoros	0.1	65.4	0.1	2.3	0.0
Congo, Dem. Rep.	0.1	69.5	0.2	6.5a	0.0
Congo, Rep. of	0.4	10.9	0.4	—	—
Côte d'Ivoire	1.1	92.0	1.3	3.2	0.0

Table 7. (Continued)

Country	Percent			Average rate of growth of irrigated area, 1973–2003	Average rate of growth of irrigated area, 2000–03
	Total irrigation equipped area / cultivated area	Irrigation-equipped area actually irrigated / total equipped area	Total water-managed area / cultivated area		
Djibouti	101.2	38.3	101.2	0.0	0.0
Egypt	97.2	94.9	97.2	0.6	1.3
Equatorial Guinea	—	—	—	—	—
Eritrea	3.4	62.5	3.4	—	0.0
Ethiopia	2.7	—	—	0.0b	0.0
Gabon	0.9	—	0.9	1.9	0.0
Gambia, The	0.6	50.3	4.3	2.3	0.0
Ghana	0.5	90.3	0.5	2.4	0.0
Guinea	5.1	100.0	5.1	2.2	0.0
Guinea-Bissau	4.1	100.0	9.4	1.3	0.0
Kenya	2.0	94.2	2.1	3.4	5.8
Lesotho	0.8	2.5	0.8	3.7	0.0
Liberia	0.3	—	3.3	1.4	0.0
Libya	22.5	67.2	22.5	3.1	0.0
Madagascar	30.6	99.5	30.9	3.5	0.0
Malawi	2.3	47.7	4.8	6.3	0.6
Mali	4.9	74.6	6.1	4.7	0.0
Mauritania	8.8	50.7	21.2	1.7	0.0
Mauritius	20.0	98.0	20.0	1.3	3.2
Morocco	15.8	97.6	15.8	1.2	0.0
Mozambique	2.7	33.9	2.4	4.4	0.0
Namibia	0.9	81.1	1.2	2.3	0.0
Niger	1.6	89.1	1.9	4.8	0.0
Nigeria	0.9	74.7	3.0	1.2	3.1
Rwanda	0.6	—	7.4	2.7	0.0
Sao Tome and Principe	17.3	—	17.3	0.0	0.0
Senegal	4.8	57.7	6.0	1.4	3.3
Seychelles	4.3	76.9	4.3	—	—
Sierra Leone	4.3	—	22.8	3.7	0.0
Somalia	14.5	32.5	14.5	2.3	0.0
South Africa	9.5	100.0	9.5	1.3	0.0
Sudan	11.2	42.9	11.2	0.4	0.0
Swaziland	26.0	90.0	26.0	0.7	0.0
Tanzania	3.6	—	3.6	4.6	2.3

Table 7. (Continued)

Country	Percent			Average rate of growth of irrigated area, 1973–2003	Average rate of growth of irrigated area, 2000–03
	Total irrigation equipped area / cultivated area	Irrigation-equipped area actually irrigated / total equipped area	Total water-managed area / cultivated area		
Togo	0.3	85.6	0.3	6.7	0.0
Tunisia	8.1	99.7	8.1	2.3	0.0
Uganda	0.1	64.5	0.8	2.7	0.0
Zambia	2.9	100.0	4.8	8.1	3.7
Zimbabwe	5.2	71.4	5.8	3.6	0.0
Northern	28.1	80.4	28.1	2.4	0.3
Sudano-Sahelian	6.9	63.3	9.2	2.7	0.4
Eastern	2.6	24.0	1.8	2.4	1.9
Gulf of Guinea	1.5	73.5	3.3	2.2	1.4
Central	0.7	47.5	2.8	0.5	3.0
Southern	4.2	80.7	4.8	3.2	0.6
Indian Ocean Islands	30.4	99.4	30.7	3.5	0.0
SSA average	3.5	71	4.5	2.3	1.3
Africa average	5.8	81.6	6.7	2.3	1.1
Asia average	33.6	66.9	34.3	2.6c	—
World average	17.7	92.4	17.6	—	—

Sources: Columns 1 and 3: cultivated areas are 2002 data from AQUASTAT (2005); columns 2 and 3: latest available data from FAO AQUASTAT database accessed November 13, 2007 (FAO 2007a); columns 4 and 5: calculated by author using ResourceSTAT database accessed November 13, 2007 (FAO 2007b).
Notes: Irrigation-equipped area includes full-control, equipped-lowland, and spate irrigation. It does not include non-equipped cultivated wetlands, inland valley bottoms, or non-equipped flood-recession cropping areas. Total water-managed area is the sum of the total area equipped for irrigation and other forms of non-equipped agricultural water management. The FAO uses irrigated area and irrigation-equipped area interchangeably. Averages not calculated for regional comparisons due to limited data access. Agro-ecological zone averages weighted by country area. Africa average does not include Western Sahara and island countries not in study.
a Data available from 1976.
b Data available from 1993.
c Average for Asia is from the years 1962–1998, calculated by Barker and Molle (2004), using FAO data.
— = data not readily available.

Irrigation technology definitions and types are from FAO (2005). Full/partial irrigation is the sum of surface, sprinkler, and localized irrigation. Localized irrigation is a low-pressure technique in which water is piped and applied to each plant as a small discharge. The main categories of localized irrigation are drip irrigation, spray or micro-sprinkler irrigation, and bubbler irrigation. Other terms used to refer to localized irrigation include micro-irrigation, trickle irrigation, daily flow irrigation, drop irrigation, sip irrigation, and diurnal irrigation. Sprinkler irrigation simulates rainfall by moving water through a pipe under pressure and discharging it with sprinkler nozzles. These systems are also known as overhead irrigation systems.

Surface irrigation, which uses gravity to move water across fields, can be subdivided into three categories: furrow, borderstrip, and basin irrigation. This classification does not refer to the method of

bringing water to the fields, which can be done with pumping systems or by manually applying water to fields from buckets.

In order to better understand the dynamics of irrigation expansion and growth, and to better appreciate the speed, extent, and nature of irrigation investments, we look at the following characteristics, within the available data:

Irrigation-Equipped Area

This indicator measures the share of total cultivated area that is equipped with irrigation facilities. As shown, only 10 countries in Africa rise to double digits. Overall, only 5.8 percent of the cultivated area in Africa is equipped for irrigation, compared with 33.6 percent in Asia and 17.7 percent for the world as a whole.

Irrigation-Equipped Area Actually Irrigated

The share of the area equipped for irrigation that is actually irrigated spans a huge range in Africa. Lower values reflect facilities that have deteriorated since construction and are no longer usable, areas in which water supply is insufficient to irrigate the entire area, and areas in which deficient management keeps available water from reaching the entire area. Overall, the average utilization rate is 71 percent in Sub-Saharan Africa and 82 percent in Africa, compared with a similar but slightly lower 67 percent in Asia.

Total Water-Managed Area

This indicator measures the share of water-managed area relative to total cultivated area. This is a broader measure than irrigation-equipped area and includes the less formal ways employed to manage water. Using this indicator raises the share of water-managed area in Africa from 5.8 percent to 6.7 percent. Although this change in the average is relatively modest, it is still significant. In some individual countries, however, the impact is far more dramatic. For example, in Rwanda, while just 0.6 percent of the cultivated area is irrigated using full or partial water control, the value rises to 7.4 percent when informal water-control practices are included. Similar changes are seen in Chad, Nigeria, Uganda, and Zambia, among others. Outside Africa, such informal water management practices are relatively less important.

Average Growth Rate

Two indicators were calculated here. The first is the average rate of expansion of irrigated area over the past 30 years. It will respond to increased investment, but slowly because of its large historical inertia. The other is the rate of expansion over a recent four-year period. This indicator will be much more responsive to investments in new irrigation. The longer-term annual rate of growth averages 2.3 percent in both Sub-Saharan Africa and Africa as a whole, though many countries show much more rapid expansion over this period. Interestingly, the recent short-term rate is only about half of this longer-term rate. This suggests a slowing of irrigation development in recent years—so much so that nearly three-fourths of African countries show a zero rate of recent area expansion. A handful of countries (Central African Republic, Kenya, Mauritius, Nigeria, Senegal, and Zambia), however, show recent growth rates of greater than 3 percent per year.

Irrigation Technology

Irrigation investment in new systems will expand irrigated area, while rehabilitation can be expected to increase the utilization of existing irrigation facilities. Modernizing existing systems may facilitate private investment in more efficient and productive water application technologies, such as sprinkler and drip irrigation. Irrigation investments may also be targeted directly at increasing the use of pressurized irrigation technology by strengthening production and marketing systems for such equipment. Of course,

private investment in such technology also responds to market access for higher-value crops and opportunities resulting from complementary investment, such as transportation. These influences need to be separated in judging impacts.

Important indicators for irrigation technology include the shares of localized, sprinkler, and surface irrigation in total equipped area, the share of equipped irrigated area over total water-managed area, and the area equipped for pressurized irrigation. These indicators are presented in Table 8.

Table 8. Irrigation technology indicators

Country	Percent					
	Area equipped for pressurized irrigation / full/partial control equipped area	Share of full/partial control irrigation-equipped area as …			Full/partial control irrigation area / total irrigation-equipped area	Full/partial control irrigation / total water-managed area
		localized irrigation	sprinkler irrigation	surface irrigation		
Algeria	8	—	8	—	90	90
Angola	—	—	—	—	100	20
Benin	54	12	42	46	90	57
Botswana	81	19	62	15	100	18
Burkina Faso	21	0	21	79	74	40
Burundi	0	0	0	100	32	7
Cameroon	24	0	24	76	88	88
Cape Verde	7	7	—	—	100	100
Central African Republic	—	—	—	—	100	21
Chad	12	0	12	88	100	19
Comoros	—	—	—	—	100	100
Congo, Dem. Rep.	0	0	0	100	95	74
Congo, Rep. of	0	0	0	100	11	11
Côte d'Ivoire	75	0	75	25	66	54
Djibouti	—	—	—	—	100	100
Egypt	11	6	5	89	100	100
Equatorial Guinea	—	—	—	—	—	—
Eritrea	0	0	0	100	19	19
Ethiopia	2	0	2	98	100	—
Gabon	—	—	—	—	71	71
Gambia, The	0	0	0	100	100	14
Ghana	20	0	20	80	100	100
Guinea	2	1	1	98	21	21
Guinea-Bissau	0	0	0	100	38	16
Kenya	62	2	60	38	100	94

Table 8. (Continued)

Country	Percent					
	Area equipped for pressurized irrigation / full/partial control equipped area	Share of full/partial control irrigation-equipped area as …			Full/partial control irrigation area / total irrigation-equipped area	Full/partial control irrigation / total water-managed area
		localized irrigation	sprinkler irrigation	surface irrigation		
Lesotho	0	—	—	—	100	97
Liberia	—	—	—	—	5	0
Libya	—	—	—	—	100	100
Madagascar	0	0	0	100	100	99
Malawi	86	10	77	11	100	48
Mali	0	0	0	100	41	33
Mauritania	—	—	—	—	100	41
Mauritius	89	9	80	11	100	100
Morocco	17	7	10	83	98	98
Mozambique	0	—	—	—	100	111
Namibia	61	18	43	39	100	79
Niger	0	—	—	—	19	16
Nigeria	0	0	0	100	81	24
Rwanda	0	0	0	100	41	3
Sao Tome and Principe	—	—	—	—	100	100
Senegal	0	0	0	100	85	68
Seychelles	92	77	15	8	100	100
Sierra Leone	0	0	0	100	3	1
Somalia	0	0	0	100	25	25
South Africa	67	12	55	33	100	100
Sudan	0	—	—	—	93	93
Swaziland	48	6	42	52	100	100
Tanzania	0	—	—	—	100	100
Togo	0	0	0	100	32	32
Tunisia	41	17	25	59	93	93
Uganda	4	0	4	96	61	9
Zambia	42	10	32	58	36	22
Zimbabwe	73	8	65	27	100	90
Northern	8	2	6	24	96	96
Sudano-Sahelian	2	0	2	41	70	47
Eastern	13	0	13	54	96	52

Table 8. (Continued)

Country	Percent					
	Area equipped for pressurized irrigation / full/partial control equipped area	Share of full/partial control irrigation-equipped area as …			Full/partial control irrigation area / total irrigation-equipped area	Full/partial control irrigation / total water-managed area
Gulf of Guinea	17	1	16	78	66	37
Central	2	0	2	57	89	52
Southern	53	11	42	29	90	74
Indian Ocean Islands	0	0	0	99	100	99
SSA average	22	2	14	30	92	71
Africa average	18	5	12	54	95	83
Asia average	2	0	2	79	96	94
World average	12	1	10	70	96	94

Sources: Latest available data from FAO AQUASTAT database accessed November 13, 2007 (FAO 2007a).[Perhaps it would be best to identify the date you accessed the database (as you did in Table 1.1) and to give the parenthetical citation--i.e., FAO 2007a)]
Notes: Full/partial irrigation includes localized, sprinkler, and surface irrigation. Total irrigation-equipped area includes areas equipped for full/partial control irrigation, equipped lowland areas, and areas equipped for spate irrigation. The aggregate value for total equipped irrigated area reported by FAO is not equal to the sum of the area for each irrigation technology type owing to differing survey years and missing data. Agricultural water management is the sum of the total area equipped for irrigation and other non-equipped areas, including wetlands and flood recession cropping. Pressurized includes localized and sprinkler only. Agro-ecological zone averages weighted by country area. Africa average does not include Western Sahara and island countries not in study.
— = data not readily available.

On-farm pressurized irrigation technologies—sprinkler and micro-irrigation—have the potential to reduce water use while increasing productivity and, for horticultural crops, improving product quality. On this score, Africa and Sub-Saharan Africa rate very well. On average, 18 percent of classically equipped irrigation area in Africa is equipped with pressurized irrigation equipment, compared with just 2 percent in Asia, and 12 percent in the world at large. This very promising feature has potential for expansion. This is based on published data, but given a lot of small-scale/small-reservoir irrigation is unreported, the actual share is likely to be somewhat lower.

2.5 Agricultural Productivity

The ultimate purpose of investing in agricultural water control is to improve human well-being, and the path to that goal runs through agricultural productivity. For the purposes of this study, agricultural productivity associated with different farming systems is indicated by value of production to allow aggregation over different types of crops. Productivity, of course, responds to a variety of influences beyond irrigation, and so changes in these indicators must be considered along with other information that might indicate the relative contributions of these other factors. Nevertheless, examining their changes over time provides a quick way of assessing overall impact and sets the stage for periodic, more detailed analysis.

We selected a pair of indicators that reflect the effect of irrigation investments on productivity (Table 9). In addition, we show some descriptive data on the comparative yields of rainfed and irrigated

crops in different countries (Table 10) and crop water productivity estimates for selected rainfed and irrigated crops (Table 11).

Irrigated Output

This indicator takes the ratio of total value of irrigated output to total value of crop agricultural output for each country (Table 9). It shows the share of crop agricultural production in each country that is derived from irrigated agriculture. For Africa, over both cash and food crops, irrigation accounts for 38 percent of the value of agricultural production. This is on par with the value usually attributed to the world as a whole (around 40 percent). It is interesting to compare this Africa share, however, with that of the share of cultivated area in which water is managed from Table 7, which is 6.7 percent. This suggests that the 6.7 percent of cultivated land on which water is managed produces almost 38 percent of crop agricultural value in these countries, a ratio of about 6 to 1. The comparable ratio for the world as a whole is around 2 to 1. This suggests a huge impact stemming from water control in Africa. Improving the quality of both formal and informal irrigation would be expected to raise this value further.

Table 9. Two indicators of agricultural productivity

Country	Value of irrigated output as share of total agricultural output (percent)	Ratio of value of irrigated output to rain-fed output
Algeria	66.1	1.95
Angola	12.3	0.14
Benin	—	—
Botswana	16.6	0.20
Burkina Faso	9.1	0.10
Burundi	9.1	0.10
Cameroon	9.4	0.10
Cape Verde	—	—
Central African Republic	—	0.00
Chad	—	—
Comoros	—	—
Congo, Dem. Rep.	0.1	0.00
Congo, Rep. of	—	—
Côte d'Ivoire	3.8	0.04
Djibouti	—	—
Egypt	100.0	—
Equatorial Guinea	—	—
Eritrea	32.3	0.48
Ethiopia	—	—
Gabon	40.9	0.69
Gambia, The	1.2	0.01
Ghana	0.4	0.00
Guinea	12.0	0.14
Guinea-Bissau	—	—

Table 9. (Continued)

Country	Value of irrigated output as share of total agricultural output (percent)	Ratio of value of irrigated output to rain-fed output
Kenya	9.5	0.10
Lesotho	—	—
Liberia	6.9	0.07
Libya	87.1	6.76
Madagascar	—	—
Malawi	8.7	0.10
Mali	10.0	0.11
Mauritania	54.8	1.21
Mauritius	—	—
Morocco	70.7	2.42
Mozambique	4.8	0.05
Namibia	—	—
Niger	—	—
Nigeria	4.4	0.05
Rwanda	5.3	0.06
Sao Tome and Principe	—	—
Senegal	16.5	0.20
Seychelles	—	—
Sierra Leone	21.6	0.28
Somalia	74.3	2.89
South Africa	—	—
Sudan	69.8	2.31
Swaziland	71.6	2.52
Tanzania	10.0	0.11
Togo	3.7	0.04
Tunisia	53.0	1.13
Uganda	0.5	0.00
Zambia	28.2	0.39
Zimbabwe	25.9	0.35
Northern	86.2	1.31
Sudano-Sahelian	58.3	1.91
Eastern	5.0	0.06
Gulf of Guinea	6.3	0.07
Central	7.3	0.09
Southern	6.6	0.13

Table 9. (Continued)

Country	Value of irrigated output as share of total agricultural output (percent)	Ratio of value of irrigated output to rain-fed output
Indian Ocean Islands	0.0	0.00
Sub-Saharan Africa	24.5	0.75
Africa average	37.7	0.61

Sources: FAO (2003); price data are world price values for year 2000 from IMPACT-WATER (Rosegrant et al. 2008).
Notes: Egypt has no rainfed production; CAR, Rep. of Congo, and Mauritius have no irrigated production; 0 = no irrigated production; agro-ecological zone averages are weighted by irrigated area; Africa averages are calculated by dividing the sum of the numerator by the sum of the denominator.
— = data not readily available.

Unit Productivity

One indicator compares the per hectare value of irrigated agricultural output to the value of an average hectare of rainfed output. The weighted average ratio for Africa is 0.61 (Table 9). This lower-than-expected value is obviously at odds with the very strong impact of irrigation shown by the previous indicator. There is a need to examine more carefully the data underlying these indicators and to reach a unified conclusion about the current state of irrigation productivity in Africa as a basis for judging the impacts of increased investment in the sector going forward.

Table 10. Ratio of irrigated and rainfed yields for selected crops in selected countries

Country	Banana	Barley	Sugar cane	Cassava	Citrus	Coffee	Cotton	Fruit	Groundnuts	Maize	Millet	Oil crops	Potatoes	Rice	Sorghum	Soybeans	Vegetables	Wheat
Algeria	0	0	0	0	IRR	0	0	2.42	RF	IRR	0	RF	0	IRR	IRR	0	2.69	0
Angola	RF	0	IRR	RF	0	RF	RF	RF	RF	RF	RF	0	RF	1.41	0	0	1.86	RF
Botswana	0	0	0	0	IRR	0	IRR	RF	RF	RF	RF	0	0	0	RF	0	RF	RF
Burkina Faso	0	0	IRR	RF	0	0	RF	1.5	RF	RF	RF	RF	RF	3.1	RF	RF	1.6	0
Burundi	0	0	IRR	RF	0	RF	RF	RF	RF	1.27	RF	0	RF	0	1.37	0	1.63	RF
Cameroon	RF	0	RF	RF	0	RF	RF	RF	RF	RF	RF	0	RF	2.4	0	RF	1.4	RF
Central African Republic	RF	0	0	RF	0	0	RF	0	RF	RF	RF	0	RF	RF	RF	0	0	0
Congo, Dem. Rep.	RF	0	RF	RF	RF	RF	RF	RF	RF	RF	RF	0	RF	3.5	RF	RF	RF	RF
Congo, Rep. of	RF	0	0	RF	0	0	0	0	RF	RF	0	0	RF	RF	0	0	0	0
Côte d'Ivoire	RF	0	IRR	RF	RF	RF	RF	0	RF	RF	RF	RF	RF	2.7	RF	RF	1.3	0
Egypt	IRR	0	0	0	IRR	0	IRR	0	IRR	IRR	0	IRR	IRR	IRR	IRR	IRR	IRR	0
Equatorial Guinea	RF	0	0	RF	0	0	0	0	RF	0	0	0	0	0	0	0	0	0
Eritrea	0	RF	0	0	0	0	0	IRR	RF	2.83	IRR	0	IRR	0	2.76	0	1.62	0
Gabon	0	0	0	RF	0	0	0	IRR	1.71	RF	0	0	0	0	0	0	IRR	0
Gambia, The	0	0	0	0	0	0	0	RF	0	RF	0	0	0	0	RF	0	RF	0
Ghana	RF	0	RF	RF	RF	RF	RF	RF	RF	RF	RF	RF	0	1.7	RF	0	RF	0
Guinea	RF	0	RF	RF	RF	RF	RF	RF	RF	RF	RF	0	0	2.45	RF	0	1.85	0
Guinea-Bissau	RF	0	0	RF	0	0	RF	0	RF	RF	RF	0	0	2.45	RF	0	0	0
Kenya	RF	RF	2.3	RF	1.7	1	RF	RF	RF	RF	RF	RF	RF	IRR	RF	0	1.2	RF
Lesotho	0	RF	0	0	0	0	0	RF	0	RF	0	0	0	0	RF	0	RF	RF
Liberia	RF	0	RF	RF	RF	RF	0	RF	RF	0	0	0	0	RF	0	RF	1.34	0
Libya	0	0	0	0	IRR	0	0	3.61	IRR	IRR	0	3.25	IRR	0	0	0	1.91	2.12
Malawi	RF	0	IRR	RF	RF	RF	RF	RF	RF	RF	RF	RF	RF	2.2	RF	0	1.8	RF
Mali	0	0	IRR	RF	0	0	RF	RF	1.59	RF	2.48	RF	0	2.14	2.58	0	2.34	IRR

Country	Banana	Barley	Sugar cane	Cassava	Citrus	Coffee	Cotton	Fruit	Groundnuts	Maize	Millet	Oil crops	Potatoes	Rice	Sorghum	Soybeans	Vegetables	Wheat
Mauritania	0	0	0	0	0	0	0	1.39	RF	RF	RF	0	IRR	IRR	2.27	0	RF	IRR
Mauritius	RF	0	1.58	0	0	0	0	RF	RF	RF	0	0	RF	0	0	0	RF	0
Morocco	0	0	0	0	0	0	IRR	1.33	2.27	2.26	RF	0	IRR	IRR	RF	0	IRR	0
Mozambique	RF	0	1.7	RF	RF	RF	RF	RF	RF	2.9	RF	RF	RF	1.4	RF	0	1.3	RF
Nigeria	0	0	1.6	RF	RF	RF	RF	RF	RF	RF	2.3	RF	RF	RF	RF	RF	1.2	2.1
Rwanda	0	0	RF	RF	0	RF	0	RF	RF	RF	RF	0	RF	2	RF	RF	1.3	RF
Senegal	IRR	0	IRR	RF	IRR	0	RF	2	RF	RF	RF	0	RF	2	RF	0	2.8	0
Sierra Leone	0	0	RF	RF	RF	RF	0	RF	RF	RF	RF	0	0	1.58	RF	0	1.36	0
Somalia	IRR	0	IRR	RF	IRR	0	1.16	IRR	RF	2.83	0	0	0	IRR	2.74	0	1.65	IRR
Sudan	IRR	0	IRR	RF	IRR	0	3	1.6	2	1.8	RF	1.5	IRR	IRR	2.7	0	3.5	IRR
Swaziland	RF	0	IRR	0	1.51	0	1.79	IRR	RF	RF	0	0	IRR	IRR	RF	0	RF	RF
Tanzania	RF	RF	IRR	RF	IRR	RF	RF	RF	RF	2.9	RF	RF	RF	2.6	RF	RF	1.4	RF
Togo	RF	0	0	RF	RF	RF	RF	RF	RF	RF	RF	RF	0	2.00	RF	0	1.25	0
Tunisia	0	0	0	0	0	0	RF	2.37	0	0	0	RF	4.29	0	RF	0	IRR	0
Uganda	RF	0	3.3	RF	0	RF	RF	RF	RF	RF	RF	RF	RF	2.2	RF	RF	RF	RF
Zambia	RF	RF	IRR	RF	RF	RF	2.7	RF	RF	RF	RF	0	RF	2.9	RF	RF	1.4	IRR
Zimbabwe	RF	IRR	IRR	RF	1.63	RF	2.39	RF	RF	1.80	RF	0	RF	IRR	RF	RF	1.66	IRR

Source: FAO (2003). Data presented are for the year 1998.
Notes: 0 = no crop production; IRR = irrigated production only; RF = rainfed production only

Table 11. Crop water productivity for irrigated and rainfed crops in kg/m^3 (1999–2001 average)

Country		Wheat	Maize	Other grain	Potato	Sweet pea	Rice	Soybean	Vegetables	Subtrop. fruit	Temp. fruit	Sugar cane	Sugar beet	Millet	Sorghum	Chickpea	Pigeon pea	Ground nut	Cotton	Cassava
Algeria	Rainfed	0.49	1.38	0.62	4.83	—	0.98	—	2.68	3.70	2.75	—	—	—	2.56	0.26	—	0.57	0.11	—
	Irrigated	1.71	1.43	0.63	8.64	—	0.21	—	5.74	3.88	3.01	—	—	—	2.75	0.28	—	0.60	0.12	—
Angola	Rainfed	0.87	0.14	—	0.64	1.00	0.09	—	1.56	2.86	—	5.04	—	0.20	—	—	—	0.11	0.13	1.73
	Irrigated	0.47	—	—	0.80	1.16	0.11	—	2.46	3.01	—	4.20	—	—	—	—	—	0.12	0.15	—
Benin	Rainfed	—	0.28	—	4.18	2.30	0.20	0.16	4.60	0.28	—	4.46	—	0.22	0.25	—	—	0.24	0.11	2.20
	Irrigated	—	—	—	1.68	—	0.27	0.20	—	—	—	3.60	—	—	—	—	—	—	—	—
Botswana	Rainfed	1.59	0.04	—	—	—	—	—	1.55	1.48	—	—	—	0.06	0.05	—	—	0.26	0.25	2.57
	Irrigated	0.58	—	—	—	—	—	—	1.45	1.44	—	—	—	—	—	—	—	0.25	0.24	—
Burkina Faso	Rainfed	—	0.38	—	12.93	1.98	0.23	0.23	1.67	1.27	—	15.17	—	0.17	0.21	—	—	0.22	0.11	0.52
	Irrigated	—	—	—	1.92	1.66	0.49	0.24	2.62	1.63	—	9.41	—	—	—	—	—	—	—	—
Burundi	Rainfed	0.19	0.27	—	0.53	1.53	0.36	0.20	3.78	2.20	—	6.35	—	0.39	0.47	—	0.34	0.28	0.13	1.92
	Irrigated	0.17	0.33	—	0.67	—	0.44	0.25	4.60	—	—	6.80	—	0.39	0.48	—	0.34	0.28	0.13	—
Cameroon	Rainfed	0.26	0.65	—	1.74	1.46	0.24	0.15	0.73	1.69	1.11	1.05	—	0.29	0.34	—	—	0.22	0.13	1.94
	Irrigated	0.35	—	—	1.61	—	0.52	0.18	0.92	—	1.43	—	—	—	—	—	—	—	—	—
Central African Republic	Rainfed	—	0.31	—	0.59	1.74	0.17	—	2.14	1.10	—	0.80	—	0.26	0.25	—	—	0.28	0.07	0.75
	Irrigated	—	—	—	0.80	—	—	—	2.43	—	—	—	—	—	—	—	—	—	—	—
Chad	Rainfed	0.48	0.24	—	2.60	2.52	0.35	—	0.87	1.48	—	26.66	—	0.16	0.24	—	—	0.34	0.08	3.63
	Irrigated	0.31	—	—	1.43	—	0.36	—	0.77	1.21	—	7.83	—	—	—	—	—	—	—	—
Congo, Dem. Rep.	Rainfed	—	0.21	—	1.84	1.20	0.09	—	2.00	2.26	—	3.56	—	—	—	—	—	0.19	—	2.03
	Irrigated	—	—	—	2.49	—	0.10	—	—	—	—	4.92	—	—	—	—	—	—	—	—
Congo, Rep. of	Rainfed	0.31	0.20	0.17	0.98	1.27	0.09	0.15	0.86	1.74	—	4.34	—	0.19	0.20	—	—	0.23	0.04	1.80
	Irrigated	0.31	—	0.23	1.20	—	0.10	0.15	—	—	—	—	—	—	—	—	—	—	—	—
Côte d'Ivoire	Rainfed	—	0.27	—	—	1.68	0.25	0.26	1.73	1.46	—	5.89	—	0.23	0.16	—	—	0.30	0.17	0.74
	Irrigated	—	—	—	—	—	0.61	0.34	2.25	—	—	6.20	—	—	0.20	—	—	—	—	—

Country		Wheat	Maize	Other grain	Potato	Sweet pea	Rice	Soybean	Vegetables	Subtrop. fruit	Temp. fruit	Sugar cane	Sugar beet	Millet	Sorghum	Chickpea	Pigeon pea	Ground nut	Cotton	Cassava
Djibouti	Rainfed	—	1.51	—	—	—	—	—	6.16	1.02	—	—	—	—	—	—	—	—	—	—
	Irrigated	—	0.53	—	—	—	—	—	2.31	0.38	—	—	—	—	—	—	—	—	—	—
Egypt	Rainfed	—	38.97	10.40	111.40	123.87	33.41	16.48	101.66	87.30	67.89	262.45	230.34	—	26.96	8.56	—	14.83	4.54	141.90
	Irrigated	2.16	3.21	1.18	9.16	10.06	0.94	0.71	11.46	9.92	7.73	12.39	26.19	—	3.07	0.97	—	1.69	0.52	—
Equatorial Guinea	Rainfed	—	—	—	—	0.60	—	—	—	—	—	—	—	—	—	—	—	—	—	0.72
	Irrigated	—	—	—	—	0.78	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eritrea	Rainfed	0.62	0.36	0.42	16.82	—	—	—	1.16	6.25	—	—	—	0.18	0.34	0.19	—	0.46	—	1.57
	Irrigated	0.31	0.46	—	2.78	—	—	—	0.90	4.01	—	—	—	—	0.44	0.12	—	0.29	—	—
Ethiopia	Rainfed	0.30	0.46	0.29	3.39	1.98	—	1.54	0.87	1.72	0.69	14.10	—	0.26	0.36	0.25	—	0.20	0.09	1.83
	Irrigated	—	0.48	—	1.92	1.29	—	1.03	0.97	1.77	0.74	9.25	—	—	0.38	0.27	—	0.22	0.10	—
Gabon	Rainfed	—	0.45	—	—	1.61	0.26	0.31	1.92	1.62	—	4.72	—	—	—	—	—	0.31	—	1.24
	Irrigated	—	—	—	—	—	0.29	0.34	2.51	—	—	5.73	—	—	—	—	—	0.53	—	—
Gambia, The	Rainfed	—	0.34	—	—	—	0.25	—	1.17	1.10	—	—	—	0.27	0.33	—	—	0.28	0.04	0.56
	Irrigated	—	—	—	—	—	0.36	—	1.36	1.34	—	—	—	—	—	—	—	—	0.04	—
Ghana	Rainfed	—	0.36	0.19	—	2.18	0.23	—	1.47	2.41	—	2.56	—	0.24	0.28	—	—	0.31	0.12	2.26
	Irrigated	—	—	0.26	—	—	0.34	—	—	—	—	2.49	—	—	—	—	—	—	—	—
Guinea	Rainfed	—	0.25	—	—	1.31	0.13	—	0.79	1.21	—	4.58	—	0.21	0.19	—	—	0.33	0.16	1.09
	Irrigated	—	—	—	—	1.58	0.30	—	1.46	—	—	4.30	—	0.28	0.25	—	—	—	0.20	—
Guinea-Bissau	Rainfed	—	0.23	—	—	—	0.12	—	1.22	1.02	—	2.98	—	0.22	0.21	—	—	0.30	0.09	1.52
	Irrigated	—	0.30	—	—	—	0.14	—	1.64	1.31	—	2.39	—	0.28	0.27	—	—	0.39	0.11	—
Kenya	Rainfed	0.59	0.65	0.81	3.52	3.92	0.95	—	4.36	4.16	1.30	11.46	—	0.22	0.32	0.16	0.17	0.66	0.04	3.11
	Irrigated	—	—	0.68	—	2.39	0.50	—	3.35	3.54	1.11	11.27	—	—	—	0.13	—	0.56	0.04	—
Lesotho	Rainfed	0.57	0.21	0.12	3.94	—	—	—	1.59	1.13	—	—	—	—	0.28	—	—	—	—	—
	Irrigated	—	—	0.15	4.85	—	—	—	1.88	1.37	—	—	—	—	—	—	—	—	—	—
Liberia	Rainfed	—	—	—	—	1.98	0.13	0.11	1.41	1.71	—	0.84	—	—	—	—	—	0.20	—	1.42
	Irrigated	—	—	—	—	—	—	—	1.89	—	—	—	—	—	—	—	—	—	—	—

Country		Wheat	Maize	Other grain	Potato	Sweet pea	Rice	Soybean	Vegetables	Subtrop. fruit	Temp. fruit	Sugar cane	Sugar beet	Millet	Sorghum	Chickpea	Pigeon pea	Ground nut	Cotton	Cassava
Libya	Rainfed	0.77	1.27	0.63	23.70	—	—	—	4.29	10.37	9.86	—	—	1.32	—	1.42	—	2.17	—	—
	Irrigated	0.36	0.52	0.34	8.50	—	—	—	3.27	5.53	5.44	—	—	0.70	—	0.80	—	1.16	—	—
Madagascar	Rainfed	0.60	0.16	—	1.00	0.96	0.22	0.24	1.90	1.17	0.58	3.01	—	—	0.10	—	—	0.16	0.13	1.40
	Irrigated	0.60	0.21	—	1.28	1.22	0.25	0.29	2.22	1.54	0.77	3.50	—	—	0.13	—	—	0.21	0.17	—
Malawi	Rainfed	0.54	0.35	—	2.56	—	0.16	—	2.00	1.33	—	12.59	—	0.15	0.18	0.11	0.17	0.20	0.05	2.68
	Irrigated	0.24	—	—	—	—	0.33	—	3.58	—	—	10.53	—	0.19	—	—	—	—	0.07	—
Mali	Rainfed	0.60	0.37	—	—	2.97	0.33	—	1.38	4.14	—	16.83	—	0.19	0.23	—	—	0.23	0.12	19.65
	Irrigated	0.50	0.33	—	—	2.37	0.34	—	2.49	4.30	—	6.61	—	0.37	0.46	—	—	0.28	—	—
Mauritania	Rainfed	0.45	0.30	0.43	103.61	1.21	1.16	—	8.57	0.81	—	—	—	0.16	0.21	—	—	0.36	—	—
	Irrigated	0.27	0.20	0.33	1.38	0.43	0.52	—	6.26	0.60	—	—	—	0.12	0.26	—	—	0.26	—	—
Morocco	Rainfed	0.32	0.13	0.31	8.53	6.55	5.43	1.73	2.74	6.30	4.73	22.41	34.81	0.78	0.36	0.22	—	0.93	0.62	—
	Irrigated	0.73	0.20	0.29	7.44	5.55	0.72	0.31	2.65	6.08	4.94	9.98	26.77	0.76	0.35	0.21	—	1.55	0.60	—
Mozambique	Rainfed	0.46	0.21	—	2.30	1.30	0.12	—	1.26	1.38	—	1.72	—	0.14	0.20	—	—	0.16	0.04	1.19
	Irrigated	0.27	0.55	—	2.77	1.56	0.13	—	1.52	1.64	—	1.79	—	—	—	—	—	—	—	—
Namibia	Rainfed	9.57	0.26	—	—	—	—	—	1.49	2.28	0.32	—	—	0.09	0.11	—	—	0.15	0.14	3.06
	Irrigated	2.36	0.24	—	—	—	—	—	1.50	2.19	0.31	—	—	—	0.11	—	—	0.15	0.14	—
Niger	Rainfed	0.58	0.23	—	123.51	5.86	0.59	—	5.22	1.90	—	15.98	—	0.16	0.09	—	—	0.15	0.69	7.95
	Irrigated	0.35	0.17	—	2.06	4.24	0.57	—	4.00	1.52	—	4.09	—	—	0.06	—	—	0.20	0.55	—
Nigeria	Rainfed	1.55	0.26	—	1.30	1.75	0.19	0.15	0.92	1.16	—	3.04	—	0.21	0.22	—	—	0.21	0.06	1.88
	Irrigated	0.74	0.58	—	1.40	—	0.37	—	1.01	—	—	2.70	—	—	—	—	—	—	—	—
Rwanda	Rainfed	0.17	0.21	—	2.15	1.42	0.28	0.14	2.07	2.31	—	4.66	—	0.30	0.34	—	—	0.23	—	1.21
	Irrigated	—	—	—	—	—	0.50	—	2.03	—	—	5.11	—	—	—	—	—	0.00	—	—
Senegal	Rainfed	—	0.24	—	489.10	3.16	0.27	—	2.49	3.54	—	19.87	—	0.27	0.31	—	—	0.41	0.14	1.09
	Irrigated	—	0.27	—	11.33	2.38	0.34	—	4.37	3.24	—	13.32	—	—	—	—	—	—	0.12	—
Sierra Leone	Rainfed	—	0.26	—	—	0.58	0.11	—	1.86	1.48	—	5.27	—	0.26	0.28	—	—	0.25	—	1.14
	Irrigated	—	0.34	—	—	0.60	0.18	—	2.52	—	—	6.05	—	0.35	0.36	—	—	—	—	—

Country		Wheat	Maize	Other grain	Potato	Sweet pea	Rice	Soybean	Vegetables	Subtrop. fruit	Temp. fruit	Sugar cane	Sugar beet	Millet	Sorghum	Chickpea	Pigeon pea	Ground nut	Cotton	Cassava
Somalia	Rainfed	0.25	0.36	—	—	11.81	—	—	—	—	—	12.36	—	—	0.22	—	—	0.65	—	7.03
	Irrigated	0.09	0.37	—	—	3.12	—	—	—	—	—	3.64	—	—	0.16	—	—	0.24	—	—
South Africa	Rainfed	2.71	0.86	0.62	27.43	3.42	1.58	0.89	8.67	10.68	7.55	13.83	—	0.32	1.53	—	—	0.91	0.27	—
	Irrigated	1.78	0.74	0.58	17.80	2.13	0.70	0.68	8.30	9.76	7.10	9.08	—	0.29	1.40	—	—	0.84	0.26	—
Sudan	Rainfed	0.59	0.18	—	17.52	0.75	0.30	—	1.62	3.07	—	18.20	—	0.07	0.20	0.56	—	0.19	0.07	0.61
	Irrigated	0.40	0.19	—	1.85	0.50	0.15	—	3.65	2.58	—	6.32	—	0.06	0.33	0.49	—	0.24	0.13	—
Swaziland	Rainfed	0.52	0.34	—	0.45	0.40	0.58	—	2.02	1.95	—	15.31	—	—	0.13	—	—	0.22	0.05	—
	Irrigated	0.47	0.39	—	0.49	0.44	0.58	—	2.38	2.42	—	13.09	—	—	0.16	—	—	0.26	0.07	—
Tanzania	Rainfed	0.72	0.38	0.92	1.59	0.39	0.17	0.07	2.71	1.48	2.45	11.19	—	0.44	0.47	0.18	0.33	0.30	0.09	2.01
	Irrigated	0.39	0.92	0.80	—	—	0.38	0.09	2.56	1.31	2.14	9.29	—	—	—	0.15	—	—	—	—
Togo	Rainfed	—	0.30	—	—	2.18	0.22	—	1.42	1.90	—	—	—	0.15	0.24	—	—	0.16	0.11	1.10
	Irrigated	—	—	—	—	—	0.38	—	1.77	—	—	—	—	—	—	—	—	—	—	—
Tunisia	Rainfed	0.93	—	0.72	5.66	—	—	—	1.37	6.15	3.50	—	23.76	—	0.24	0.48	—	—	0.58	—
	Irrigated	1.56	—	—	12.46	—	—	—	1.08	5.05	2.93	—	29.65	—	0.20	0.41	—	—	0.48	—
Uganda	Rainfed	0.31	0.45	—	1.93	1.16	0.22	0.33	1.71	1.69	—	1.36	—	0.42	0.40	0.14	0.28	0.20	0.02	3.03
	Irrigated	0.35	—	—	—	—	0.36	—	—	—	—	3.35	—	—	—	0.16	—	—	—	—
Zambia	Rainfed	4.50	0.34	0.22	1.67	2.73	0.10	0.38	1.71	1.53	—	14.02	—	0.20	0.19	—	—	0.11	0.10	1.17
	Irrigated	1.82	—	0.29	2.06	3.36	0.25	0.48	2.42	2.02	—	11.08	—	—	0.25	—	—	—	0.28	—
Zimbabwe	Rainfed	4.44	0.30	1.30	3.45	0.47	0.31	0.53	1.79	1.34	1.57	18.61	—	0.07	0.17	—	—	0.17	0.07	1.07
	Irrigated	1.74	0.48	1.54	3.67	0.50	0.31	0.59	2.66	1.66	1.87	12.17	—	0.08	0.20	—	—	—	0.15	—

Source: IFPRI IMPACT-WATER simulations (Rosegrant et al. 2008).
Notes: — = data not available.

A second indicator presents irrigated and rainfed crop water productivity for selected crops for African countries (Table 11). Productivity is measured as kilograms of output produced compared to cubic meters of water used, either from irrigation or precipitation. While irrigated productivity (which also includes precipitation) is generally higher, final outcomes depend on the particular rainfall of the year and location.

Comparative Crop Yields

Although the data are too sparse to use as a comprehensive set of indicators, the data shown in Table 10 shed light on the question of rainfed versus agricultural productivity. As seen, the yield ratios in the table generally range between about 1.5 and 3.0, suggesting that irrigated yields are typically one and one-half to three times those of rainfed crops. For the two important crops (rice and vegetables) grown in a majority of the countries for which data are available, simple average values of the yield ratios in the reporting countries are 1.5 for both rice and vegetables. These indicative values are intermediate to the ones discussed in the two previous sections.

Poverty and Food Security

Irrigation investments must ultimately be designed to reduce poverty and improve food security for rural populations. In addition, through forward and backward linkages, agricultural growth can affect the entire economy, reducing poverty in the nation as a whole.

Four indicators are presented here to assess the impacts on poverty and food security (Table 12). Because of the comprehensive nature of these indictors and the various other factors that influence them, it would typically be necessary to disaggregate them regionally, focusing on areas in which major irrigation investments were planned. In response to sustained major investments, however, the national averages could be expected to respond as well.

National Poverty Headcount Ratio

This indicator measures the share of the population with incomes falling below the national poverty line. Its average for Sub-Saharan Africa is 51 percent (Table 12). This compares with 17 percent in East Asia and the Pacific and 40 percent in South Asia, and 25 percent for the world as a whole. This indicator would respond to rising incomes throughout the economy as irrigation investment increases agricultural productivity and stimulates economic growth.

Rural Poverty Headcount Ratio

This indicator is similar to the previous one, except that it considers only the rural population and uses a separate, usually lower, poverty line linked to costs in rural areas. Due to the wide range of reporting years for this indicator, however, average values are not calculated. This indicator would respond to the irrigation-induced increase in farm incomes, to employment created by expanded agricultural areas and shifts to more labor-intensive crops, and to growth in rural areas stimulated by forward and backward linkages to input suppliers and output processors.

Economically Active Population in Agriculture

This indicator measures the share of the working population engaged in agriculture in a country. Values shown span a huge range, from 8 percent in South Africa to 90 percent in Rwanda. On average, 54 percent of the economically active population in Africa is engaged in agriculture, compared with 28 percent in Asia and 22 percent for the world as a whole. This indicator might be expected to rise locally in response to irrigation investments, but to decline over the longer term as the structure of the economy changed and industrial and service sectors employed a larger share of the workforce. As in the case of all the indicators, targets would have to be set locally in cognizance of local conditions and goals.

Caloric Intake

This indicator, caloric intake per capita, measures nutritional status. It should respond to increased food production by subsistence producers and increased rural incomes more broadly, stimulated by irrigation-led agricultural growth. The average caloric intake over the period 2003 to 2005 for Africa is 2,364 kilocalories(kcal)/capita/day, about the same as South Asia and 13 percent below the world average.

Table 12. Poverty and food security

Country	Poverty head-count ratio at national poverty line (%)	Rural poverty head-count ratio at rural poverty line (%)	Economi-cally active population in agriculture (%)	Caloric intake / capita (kcal/capita/ day)	Agricul-tural value added (% GDP)	Annual growth in agricul-tural value added (%)	Agricul-tural value added per worker (constant 2000 US$)
Algeria	23	30	23	3,100	8	—	2,219
Angola	—	—	71	1,880	8	10	196
Benin	29	33	50	2,290	32	—	536
Botswana	—	—	44	2,200	2	-1	367
Burkina Faso	46	52	92	2,620	32	3	179
Burundi	68	65	90	1,630	35	—	64
Cameroon	40	50	55	2,230	20	3	677
Cape Verde	—	—	20	2,380	9	4	1,510
Central African Republic	—	—	69	1,900	56	3	384
Chad	64	67	71	1,980	21	3	225
Comoros	—	—	72	1,800	51	-10	436
Congo, Dem. Rep.	—	—	61	1,500	46	3	149
Congo, Rep. of	—	—	37	2,330	5	—	—
Côte d'Ivoire	—	—	45	2,520	23	1	817
Djibouti	—	—	77	2,170	4	4	65
Egypt	17	23	31	3,320	15	3	2,128
Equatorial Guinea	—	—	68	—	3	1	1,198
Eritrea	53	—	76	1,530	23	5	63
Ethiopia	44	45	81	1,810	47	11	162
Gabon	—	—	33	2,760	5	2	1,663
Gambia, The	61	63	78	2,140	33	5	243
Ghana	29	39	56	2,690	37	6	332
Guinea	40	—	82	2,540	20	4	193
Guinea-Bissau	66	—	82	2,050	60	6	246
Kenya	52	53	74	2,040	27	5	345
Lesotho	68	54	38	2,430	17	2	412
Liberia	—	—	65	2,010	66	—	—
Libya	—	—	5	3,020	—	—	—

Table 12. (Continued)

Country	Poverty head-count ratio at national poverty line (%)	Rural poverty head-count ratio at rural poverty line (%)	Economi-cally active population in agriculture (%)	Caloric intake / capita (kcal/capita/ day)	Agricul-tural value added (% GDP)	Annual growth in agricul-tural value added (%)	Agricul-tural value added per worker (constant 2000 US$)
Madagascar	71	77	72	2,010	28	2	175
Malawi	65	67	81	2,130	33	12	109
Mali	64	76	79	2,570	37	6	244
Mauritania	46	61	52	2,790	24	12	356
Mauritius	—	—	10	2,880	6	-4	5,338
Morocco	19	27	33	3,190	13	23	1,657
Mozambique	54	55	80	2,070	27	9	157
Namibia	—	—	38	2,290	12	-1	1,134
Niger	63	66	87	2,140	40	6	157
Nigeria	34	36	30	2,600	23	—	1,025
Rwanda	60	66	90	1,940	42	0	217
Sao Tome and Principe	—	—	62	2,600	17	—	—
Senegal	33	40	72	2,150	17	-3	227
Seychelles	—	—	77	2,380	3	5	433
Sierra Leone	70	79	60	1,910	46	—	—
Somalia	—	—	69	—	—	—	—
South Africa	—	—	8	2,900	3	-13	2,636
Sudan	—	—	57	2,290	34	7	666
Swaziland	69	75	32	2,320	11	2	1,275
Tanzania	36	39	79	2,010	46	4	306
Togo	32	—	57	2,020	44	—	353
Tunisia	8	14	23	3,280	12	3	2,686
Uganda	38	42	78	2,380	33	5	235
Zambia	68	78	67	1,890	23	2	211
Zimbabwe	35	48	60	2,040	19	—	205
Northern	17	24	28	3,232	12	6	2,008
Sudano-Sahelian	32	34	71	2,118	28	4	340
Eastern	45	47	80	1,972	40	7	232
Gulf of Guinea	31	31	39	2,540	27	1	814
Central	7	9	61	1,743	34	4	276
Southern	30	33	43	2,421	15	-2	1,248

Table 12. (Continued)

Country	Poverty head-count ratio at national poverty line (%)	Rural poverty head-count ratio at rural poverty line (%)	Economi-cally active population in agriculture (%)	Caloric intake / capita (kcal/capita/ day)	Agricul-tural value added (% GDP)	Annual growth in agricul-tural value added (%)	Agricul-tural value added per worker (constant 2000 US$)
Indian Ocean Islands	64	69	68	2,055	27	1	495
SSA average	51	—	59	2,192	30	3	575
Africa average	—	—	54	2,364	27	3	812
East Asia and Pacific	17	—	—	2,665	13	5	465
South Asia	40	—	—	2,392	19	3	417
Asia average	—	—	28	—	—	—	—
World average	25	—	22	2,713	3	3	941

Sources: Columns 1 and 2: latest available data from World Development Indicators (World Bank 2008), with the exception of the averages for SSA, East Asia, the Pacific, South Asia, and the World, which are from the PovcalNet database accessed November 20, 2007 (PovCalNet 2007) using the default poverty line of $38.00 per month at the 2005 purchasing power parity (the $1.25-a-day line); column 3: AQUASTAT (2005); column 4: FAOSTAT data accessed April 12, 2008 (FAO 2008)for the years 2003–2005; columns 5 and 7: World Development Indicators (World Bank 2008) for year 2005; column 6: World Development Indicators (World Bank 2008) for year 2006.
Notes: The rural poverty rate is the percentage of the rural population living below the national rural poverty line. Averages for columns 1 and 2 are not calculated using World Bank (2008) data due to the variation in years reported. The averages for column 2 are not given in the PovcalNet database. Agro-ecological zone averages are weighted by population.
— = data not available.

Agricultural Value Added

Three indicators were calculated here. The first is the share of GDP generated through agricultural production. This indicator responds to increased investment and—holding other sector growth constant—should increase as productivity rises. In the long term, however, this indicator will decrease as backward and forward linkages bring growth to industrialized sectors of the economy. This trend should also be observed in the annual growth of agricultural value added, which for Africa for the year 2006 was on par with the world average. Finally, the average value added per worker can be expected to increase under sustained investment. For the year 2005, the average for Africa was $812 per worker, which is close to the world average; however, there are a few outliers in this category, namely, northern African countries, Mauritius, and South Africa, which all have higher value added per worker.

3. SUMMARY AND CONCLUSIONS

The World Bank and other donors are planning a significant increase in irrigation investment levels in Africa. This paper identifies and defines a set of indicators to measure the effect of such increases and establishes baseline values for the indicators. The paper also compares baseline values for Africa with values of the same indicators from other country groupings to illustrate the relative position. The paper develops indicators in six categories—institutional framework, water resource utilization, irrigation area, irrigation technology, agricultural productivity, and poverty and food security. In all cases, we have selected indicators that could reasonably be expected to respond in some way to increased irrigation sector investment, allowing the impacts of the investment program to be monitored and assessed.

From our analysis, we see that African countries are characterized by having less renewable water per unit area and a higher population density than the world as a whole. A higher percentage of their populations are engaged in agriculture, and farm size is slightly smaller than average—slightly more than one hectare per agricultural worker. Strikingly, African countries, on average, withdraw less than half as much water for human use as does the world as a whole, and the irrigated share of their cropland is less than one-third of the world average. Total water withdrawals and agricultural withdrawals in Africa are but a fraction of those prevailing in Asia and in the world as a whole. Both are expected to rise as a result of increased irrigation investment. Surface water storage capacity in Africa, as a share of average river discharge, is on par with the global average. This storage is very unevenly distributed, however, and much of it is used solely for hydropower generation. Although groundwater utilization in northern African countries remains high, average groundwater utilization in Sub-Saharan Africa is less than 20 percent of renewable supplies. Groundwater is a resource particularly well suited for small-scale irrigation and for multiple-use systems.

The share of cultivated area equipped for irrigation in Africa is about one-third of the equipped share in the world as a whole and less than one-fifth of the value for Asia. Utilization rates of installed capacity are comparable in Africa and Asia. A remarkably high percentage of irrigated land in Africa employs pressurized water application, though the great bulk of that area is in Malawi, Zimbabwe, and South Africa. Rates of irrigation expansion in Africa are low over the past 30 years and extremely low for a recent three-year period, averaging just 1.1 percent. However, some investment increase has been observed since 2005.

In terms of how irrigation affects the performance of the agricultural sector, aggregate data show that irrigated agriculture produces 38 percent of the crop agricultural value in Africa from less than 6.7 percent of cultivated land. In a somewhat contradictory result, however, unit productivity values show an output advantage for irrigated agriculture that is considerably smaller. Irrigated to rainfed crop yield ratios generally run between 1.5 and 3.0. More analysis of the larger-scale impacts of irrigation relative to rainfed crop production is required.

Poverty incidence in Africa is considerably higher than in Asia and the world at large, and Africa contains a large number of so-called “ultra-poor.” Almost twice as much of the economically active population is engaged in agriculture in Africa than in Asia. Whether rural employment generation is an objective in a particular setting (determining whether this indicator would come into play) must be decided on a case-by-case basis. Calorie availability per capita is on par with South Asia, yet lower than East Asia and the Pacific, and 20 percent below the world average, providing ample room for targeting improvement.

The impact indicators and baseline values developed in this paper were selected to form a comprehensive and coherent set, given constraints imposed by data availability. The various FAO databases provide a very useful primary source of time series information for populating many of the hydrologic and agricultural indicators. World Bank investment programs in specific African countries could be very useful vehicles for refining the quality and coverage of these data, and such sector work should be included in country irrigation investment programs. The data collected should honor the FAO variable definitions so that new information will augment and be consistent with existing data.

An area that requires particular attention is that of comparative rainfed and irrigated agricultural yields and aggregate output. Another area of uncertainty is that of per hectare irrigation investment costs across different regions and farming systems. There have been recent improvements in this kind of data, but the African continent remains largely understudied in this respect compared with South and Southeast Asia.

A final important gap relates to irrigation institutions. A coherent framework of concepts, variables, and indicators is needed in order to assess changes in this area. To support such a framework, a database of policies, laws, charging data, and other information is required to populate institutional indicators and allow changes to be measured. Most potential investors expect institutional frameworks to improve as investments increase. But the expected changes do not form a clear pattern or exhibit a linear progression. It is thus difficult to imagine and assess impacts on institutions in a generic way. At the same time, data characterizing sector institutions are scarce and fragmented. Additional effort is clearly required to conceptualize expected favorable institutional changes and establish a regionwide information base that could be used to populate a set of indicators, once defined.

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IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org

IFPRI ADDIS ABABA

P. O. Box 5689
Addis Ababa, Ethiopia
Tel.: +251 11 6463215
Fax: +251 11 6462927
Email: ifpri-addisababa@cgiar.org

IFPRI NEW DELHI

CG Block, NASC Complex, PUSA
New Delhi 110-012 India
Tel.: 91 11 2584-6565
Fax: 91 11 2584-8008 / 2584-6572
Email: ifpri-newdelhi@cgiar.org